526, 527, 528

MICROWAVE AMPLIFIER
MODEL 528A, Serial No. 204

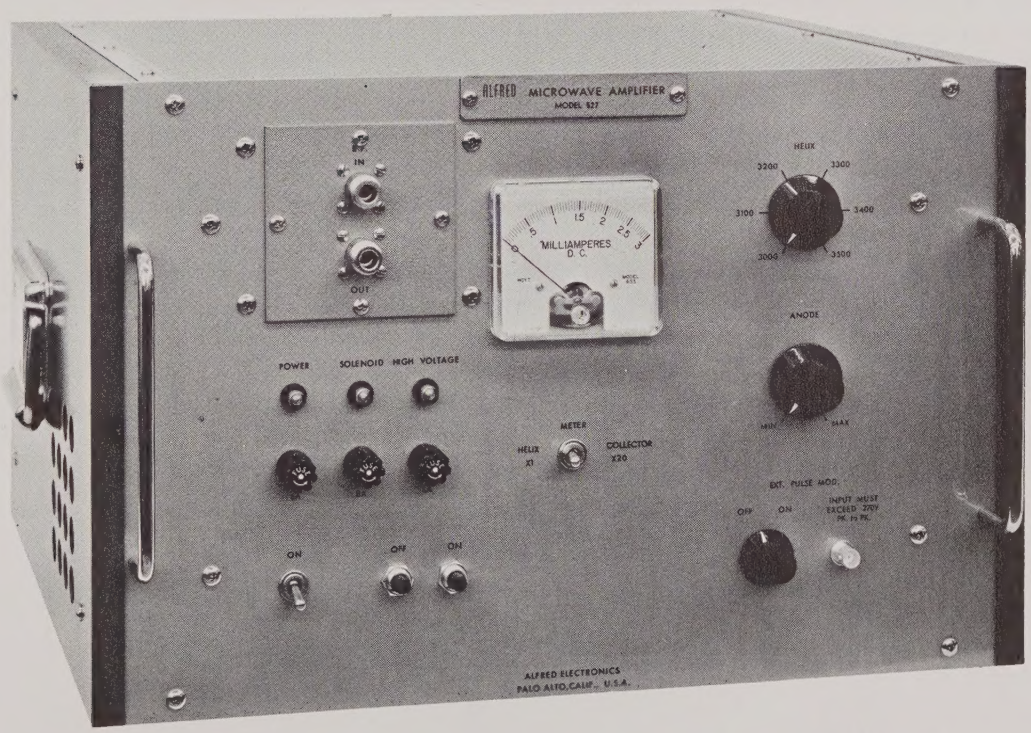
Spec 1138

CODE ~~3260~~
2310

ALFRED ELECTRONICS 3176 PORTER DRIVE, PALO ALTO, CALIF.

MICROWAVE AMPLIFIER
MODEL 5284, Serial No. 204

Spec 1138



214-6525 SD

ADDENDUM SHEET

Model 526 only

Date	Change Number	Effective S/N	Description
2-27-65	12892	188-up and all replacement tubes	On the MEC tube # M2405F used in the Model 526, the anode voltage range specification has been changed to 2500 - 3400 V. Before operating the instrument, refer to the tube data sheet for the recommended anode voltage for the tube installed. If this voltage is 2700 volts or greater, follow the operating procedures given in this manual. If the recommended anode voltage is less than 2700 volts, note the following changes in the operating procedures: Paragraph 3-2, step 6: The front panel ANODE control may have to be adjusted to a setting below the MAX position to give optimum performance. When measuring COLLECTOR X20 current as specified in this step of the procedure, DO NOT adjust the internal ANODE CALIB. control. Instead, turn the front panel ANODE control slowly CCW, away from the MAX position, until rated cathode current is obtained. Place a small piece of colored tape, or an ink mark, on the panel to identify this optimum setting of the ANODE control. Paragraph 3-4, step 3: When raising the ANODE voltage slowly from the MIN setting, advance the ANODE control only as far as the "optimum setting" ink or tape mark established as above. When a replacement M2405F tube is installed, carry out the above steps as applicable for the particular anode voltage recommended on the data sheet for the replacement tube.

MICROWAVE AMPLIFIER
MODELS 526, 527, 528, 528A

SPECIFICATIONS

	526	527		528	528A
Frequency Range:	12.4 to 18 Gc	8 to 12.4 Gc	8 to 11 Gc	7 to 11 Gc	7 to 11 Gc
Power Output:	1 watt into 50Ω load	2 watts into 50Ω load	5 watts into 50Ω load	5 watts into 50Ω load	10 watts into 50Ω load
Gain (@ rated power output)	30db minimum	27 db minimum	27db minimum	30db minimum	30db minimum
Spurious Modulation:		35 db minimum			
Gain (small signal @ 200 mw output):		30 db minimum			
Gain Adjustment:		0 to 10 db gain reduction at 200 mw by adjustment of front panel ANODE voltage control from maximum to minimum.			
Noise Figure:		35 db maximum			
Modulation:		Greater than 30 db gain variation by 300 volts external pulse.			
RF Impedance:		50 Ω - 527, 528			
RF Connectors:		Type N female receptacle, 527, 528, 528A 541 U choke flange - 526			
Metering:		Helix current, and collector current on 4" front panel meter, selected by front panel switch. Helix and cathode tip jacks available at rear for checking with external precision voltmeter.			
Front Panel Controls:		ANODE voltage (maximum to minimum setting). HELIX voltage (3000 to 3500 volts). METER current switch.			
Power Supply:		All TW tube electrode voltages, and solenoid current are regulated. Protective relay shuts off TW tube power upon helix overcurrent.			
Input Voltage:		105 to 125 volts, 50/60 cps, approximately 1200 VA.			
Physical:		Bench with perforated metal dust cover. Handle sides are removable to permit mounting in standard 19" rack. Height: 12 1/4" Width: 19" Depth: 16" from panel, 17 1/2" overall.			
Finish:		Panel, grey. Sides, top and bottom, dark metallic grey.			
Weight:		100 pounds.			

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SECTION 1 - GENERAL

1-1 DESCRIPTION

The ALFRED Models 526, 527, 528 Microwave Amplifiers are stable, high gain, broadband power amplifiers of microwave signals in the frequency range of 7.0 to 18 Gc. They are compact, versatile instruments consisting of a traveling wave tube, its focusing solenoid, and a power supply for all required operating voltages. Electrical protection is provided to prevent damage to supply or TW tube from misadjustment or failures. Thus the varied and unique traveling wave tube characteristics may be conveniently applied to laboratory and systems use. Some possible applications are:

1. Power amplification of wide band signal generator outputs or complex modulated RF signals.

2. Amplification of RF pulses with rise times as short as a few millimicroseconds.

3. Isolation of a load from a microwave signal source.

4. Generation of extremely stable microwave oscillations either at fixed frequency or tunable over a wide range, using an external resonant feedback network.

On the front panel of the Models 526, 527, 528, provisions are made for either Type N or wave guide fittings for RF input and output. Also provided are controls for ANODE and HELIX voltages to optimize performance for specific applications. A panel meter may be selected by a switch to monitor either helix or collector current.

The TW tube requires no RF adjustment, is encapsulated for protection, and is easily replaced. The TW tube RF connectors may be mounted on the front panel or on the rear deck, or the RF connectors may be reversed in the field.

The Models 526, 527, 528 are built as convenient laboratory bench instruments. However, simply by removal of outside sheet metal sides, it may be mounted in a standard relay rack.

SECTION 2 - THEORY OF OPERATION

2-1 GENERAL DESCRIPTION OF TW TUBE

The traveling wave tube physical arrangement is indicated in Figure 1. The electron gun produces a beam of electrons which travels down the axis of the helical wire coil to the collector. The magnetic flux from the surrounding solenoid restricts the beam to travel axially along the tube just inside the helix.

RF signals at low impedance are connected to the helix at the electron-gun end and travel down the metallic path of the helix. The velocity of the electron beam is critically adjusted by the potential difference of the cathode and helix so that the beam velocity down the axis is just a little faster than the progressive RF signal on the helix. The field of the helix RF signal causes the electrons to bunch, so that at the collector end, their increased field returns to the helix an amplified signal which is conducted out to the load. Reflections down the helix are absorbed by the attenuator, consisting of a lossy helix externally placed and positioned between input and output. Due to the low impedance connections to the helix and the relatively long effective path provided by the TW tube, uniform amplification over a broad band of frequencies is achieved.

A more complete description and associated pertinent information are presented in the Engineering Notes, at the end of this manual.

2-2 TW TUBE PERFORMANCE CHARACTERISTICS

Gain and Power Output Figure 2 Model 526, Figure 3 Model 527, Figure 4 Model 528 show typical curves of small signal gain, gain at rated output, and maximum power output as a function of frequency. These curves are taken at rated helix voltage. The small signal gain is better than 30 db over the frequency range. Gain at rated output is greater than 30 db over the same frequency range. Anode attenuation is greater than 10 db by panel control and grid attenuation is greater than 30 db by an external 300 volt pulse. Grid modulating pulse voltage must exceed 270 volts. Pulses of lower voltage will cause improper tube operation.

2-3 RF LOAD

The TW tube may be operated at any collector current up to rated value into an RF load with any voltage standing wave ratio in the rated frequency range. Performance will be stable without spurious oscillations, but output power will be less into mismatched loads.

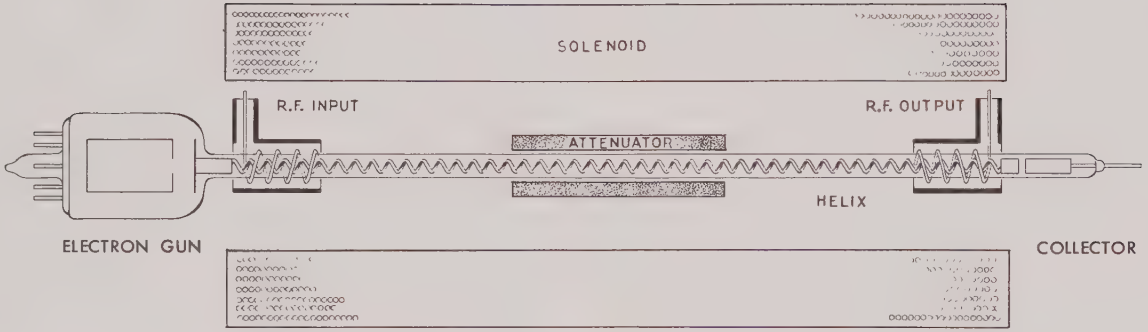
2-4 POWER SUPPLY

1. An electronically regulated solenoid current source providing 5 amperes at approximately 75 volts.

2. A transistor regulated AC heater supply for the TW tube providing 6.3 volts insulated for full cathode DC voltage.

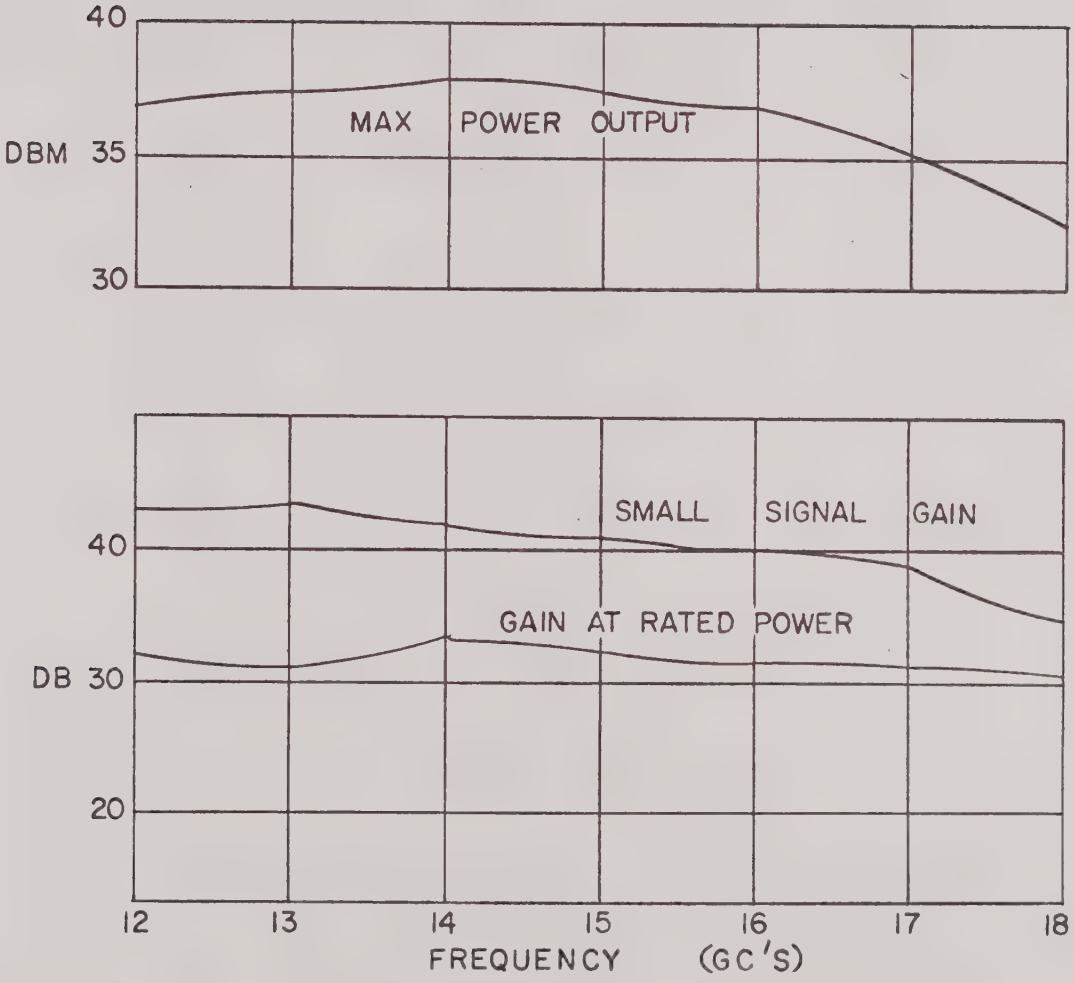
3. An electronically regulated Helix, Anode and Collector supply providing voltage from 2700 to 3500 volts with 300 mv peak to peak ripple or less.

   An overcurrent relay causes shutoff of all high voltage should helix current exceed 3 ma for any reason.



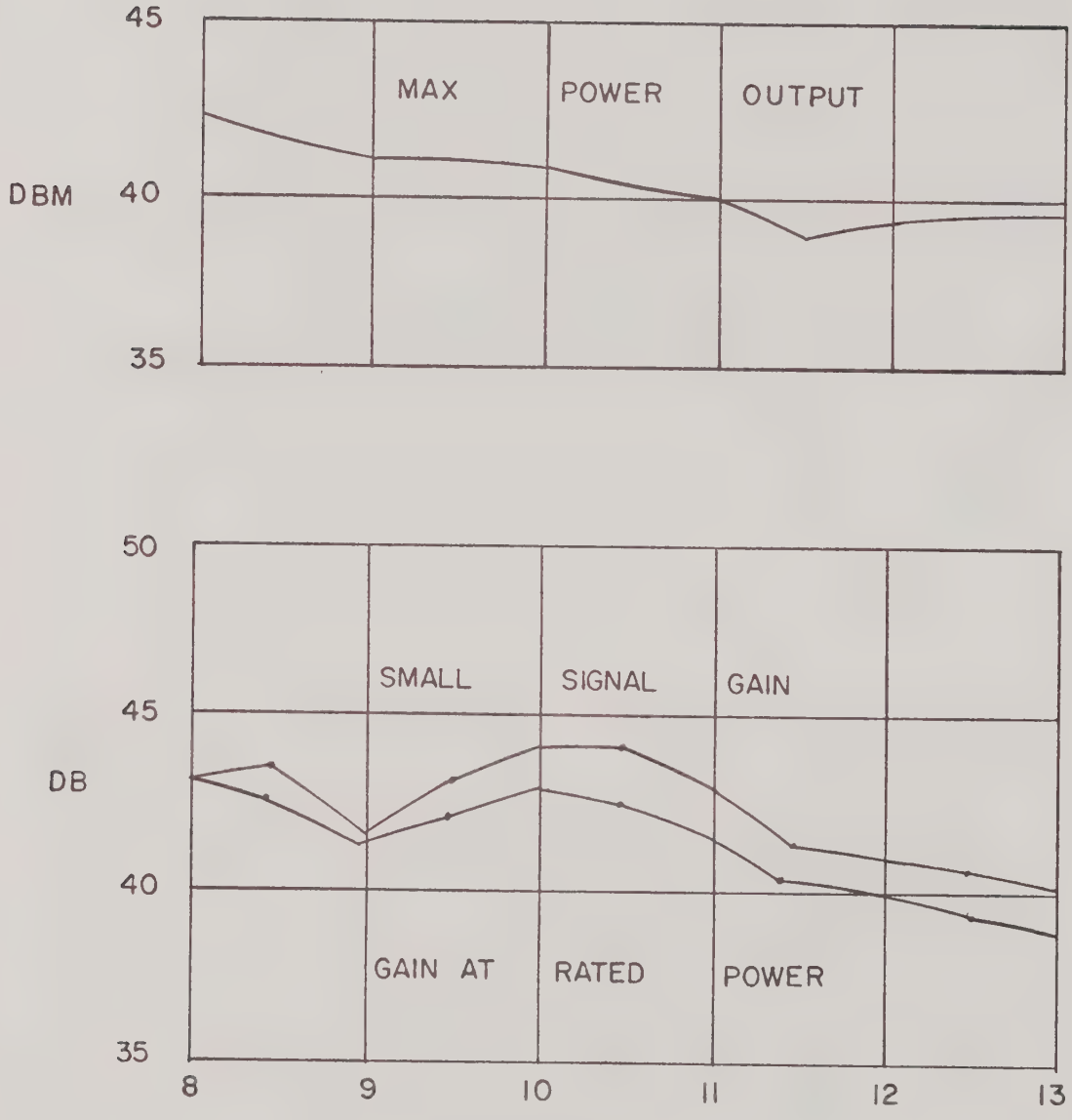
Schematic View of Traveling-Wave Tube

FIGURE 1



TYPICAL MODEL 526 POWER OUTPUT AND GAIN VS FREQUENCY

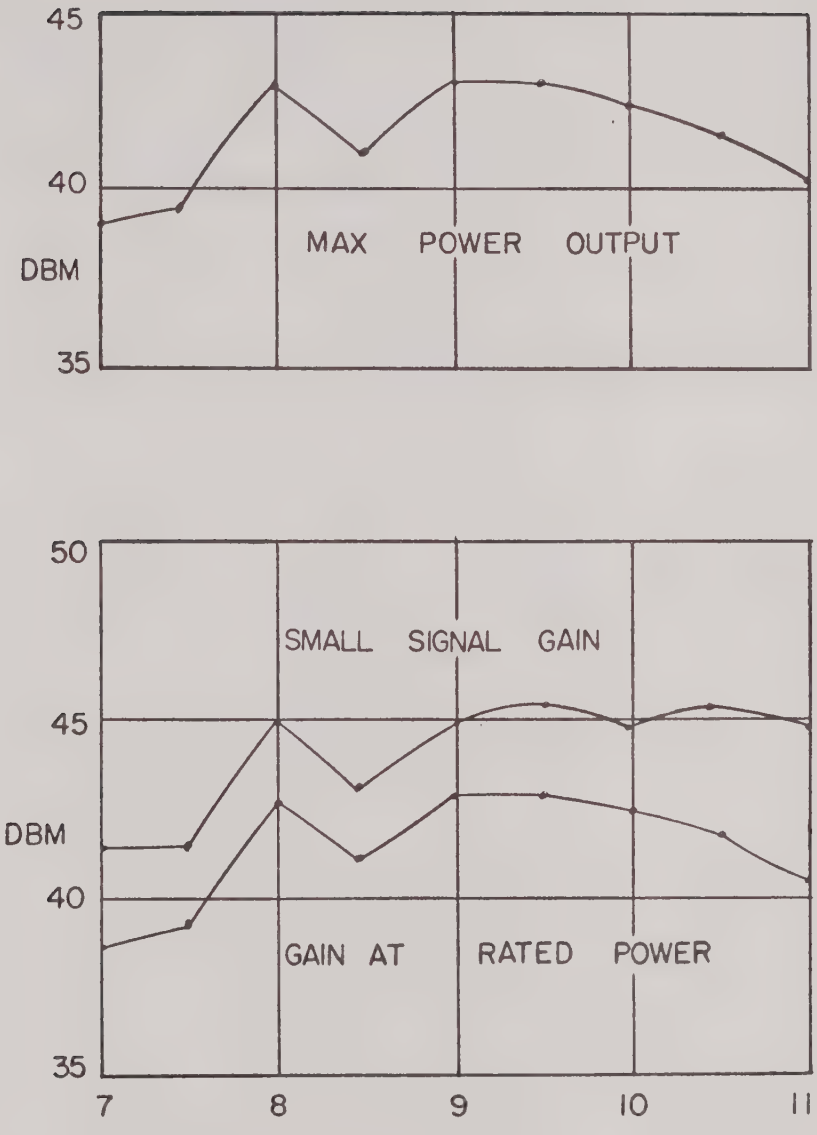
FIG. 2



TYPICAL MODEL 527 POWER OUTPUT

AND GAIN VS FREQUENCY

FIG. 3



TYPICAL MODEL 528 POWER OUTPUT
AND GAIN VS FREQUENCY

FIG. 4

2-5 FUNCTION OF CIRCUITRY

Function of circuitry--see schematic in back of manual.

2-6 POWER AND SWITCHING

All power to the instrument is fed through POWER switch SW1 and the normally closed thermal switch located in solenoid L2. The thermal switch is set to open at approximately 200° F. When the power switch SW1 is closed, transformers T1 and T3 are immediately energized through POWER fuse F2 to provide filament voltages to the -300 volt grid supply, the 56 volt screen supply, and the 200 volt supply required in the helix overcurrent relay RY2 circuit. Helix overcurrent relay RY2 picks up through tube V9. The high voltage circuit powered by transformer T2, through fuse F1 and contacts of relays RY1 and RY2 may be energized by depressing the "High Voltage On" switch SW3 to pick up relay RY1. Interlock contacts on RY1 maintain the circuit when SW3 is released. The H.V. supply may be de-energized by depressing HV OFF switch SW2 or should overcurrent relay RY2 drop out due to excessive helix current.

2-7 SOLENOID SUPPLY

Current regulated solenoid supply input power is applied to silicon rectifiers SR29 through SR32, through POWER switch SW1, SOLENOID fuse F3, and the normally closed Solenoid Thermal switch. Current from the rectifier is filtered by L1, C29 and C30. R100 and R101 serve as a current sensing resistance developing a voltage which is compared with the reference voltage from ZD2. Any error developed in the comparison circuit is amplified by Q3 and applied to the base of the current control transistor Q2. R95-98, are current shunts to minimize the loading on Q2. Diode SR34 and R94 comprise a circuit to protect ZD2 from overloads at turn on. R104 "SOLENOID I CALIB" is used to compensate for circuit element tolerances. The regulated current is then fed to focusing solenoid L2. A normally closed thermal switch mounted in L2 opens if its temperature exceeds 200° F to remove DC power from solenoid. Excessive temperature may damage both TW tube and solenoid and could result from blower failure or abnormal ambient. Blower power is obtained through fuse F3. R105 calibrates 1 amp/volt test points.

2-8 LINE REGULATED SUPPLIES 6.3V, 300 V, and 56 V

Regulation of these supplies is accomplished by regulating the input to the primary of transformer T3. Transistor Q1 is effectively in series with the input transformer T3. Rectifiers SR23 to 26 are connected in a bridge network to provide DC to the transistor for the positive and negative swings of the AC line. The drop across the transistor is automatically adjusted so the voltage to T3 will be maintained constant, independent of line voltage changes. The drop

across the transistor is varied by employing Zener diode ZD1 as a stable reference through which output voltage change controls net transistor base current. On one half cycle forward transistor emitter to base bias is developed through 5 K resistor R88 and the low forward diode resistance of the Zener. On the other half cycle the bias current is opposed by any output voltage in excess of the Zener breakdown voltage and is developed through the low forward diode resistance of SR22. Biasing is set so that variation of ± 10% maximum from nominal 115 volts rms input, will cause corrective changes in the drop across Q1 for less than ± 3% change in the output. Capacitor C24 serves to average the DC current pulses through the transistor and bypass any AC ripple. C23 operates in the same manner for the base bias current. Taps are provided on the transformer T3 primary to compensate for voltage tolerance of the Zener diode.

2-9 HIGH VOLTAGE SUPPLY

When transformer T2 is energized by depressing the H.V. ON switch approximately 4000 volts DC is supplied to the series control tubes, V1, V2, and V3 in parallel from the voltage doubling network of capacitors C4 and C5, rectifiers SR3 to 11, SR12 to 20 and winding 2-3 of T2.

The series regulating tubes V1, V2 and V3 in parallel are controlled by amplifier tubes V4 and V5 to provide an electronically regulated supply with a nominal value of 3500 volts. Reference voltage is developed across V6, V7, and V8 and is compared with the supply output voltage at the grids of differential amplifier V5. The amplified difference at the plates of V5 is applied to the cathode and grid of the left half of V4 by employing the right half of V4 as a cathode follower. The difference voltage is further amplified and appears at the plate of V4 left half as a single ended output to drive the grids of the series regulator tubes V1, V2 and V3. The series tubes will conduct more or less as required to reduce the difference in grid voltages to the differential amplifier V5 to zero and thereby maintain the supply output at -3500 volts.

The supply voltage is sampled by a resistor divider network consisting of HELIX CALIB. potentiometer R36 and precision resistors R37 through R44 to provide the input to grid (pin 2) of differential amplifier V5.

The positive side of the supply is connected to ground. The capsule and collector of the TW tube are connected to the ground side and the cathode to the -3500 volt side of the supply.

Helix voltage is obtained from the left half or pentode side of V9 acting as a cathode follower. The grid of V9 (pin 7) is connected to front panel control potentiometer marked HELIX and can be varied from approximately 0 to -500 volts with respect to ground or conversely from +3000 to +3500 volts with respect to TWT cathode. The plate voltage of V9 left half is supplied by T2 winding 4-5

through rectifier SR2B and filter capacitor C3. HELIX CALIB potentiometer R36 provides compensation for component tolerance variations so that accurate calibration of HELIX control potentiometer can be made.

Helix current through R67 varies the bias on tube V9 right half. When the helix current reaches maximum safe value, the bias is increased sufficiently to cut off the tube and drop out overcurrent relay RY2. Contacts of RY2 open the H.V. circuit to remove all high voltages from the TWT electrodes. Voltage for the plate of V9 right half and RY2 in series is provided by T1 winding 3-4 through resistor R1, rectifier SR1 and filter capacitor C1.

Filaments of series tubes V1, V2 and V3 are connected in series so that failure of one will turn off all and prevent overloading of operative tubes. Heaters of amplifier tubes V4, V5 and overcurrent relay tube V9 are also connected in series so that open circuit on any heater will turn all off, dropping out relay RY2 and removing high voltage.

Anode voltage is obtained from the wiper of front panel potentiometer marked ANODE through the resistor divider string of R72 through R83. ANODE CALIB potentiometer R72 provides compensation for component tolerance variations for calibrating the ANODE potentiometer R73. ANODE potentiometer R73 permits setting of TWT anode voltage to desired operating value.

Helix, Anode and Cathode tip jack connections are provided on the rear of the instrument for external voltage measurements.

Switch SW5 selects either Collector or Helix current to be measured with meter M1. Shunts R84 and R85 provide scale multiplication. During the switching action of SW5 only the meter connections are broken, the shunts remain in their respective circuits so that neither the collector or helix circuits are broken during switching.

2-10 EXTERNAL PULSE MOD AND GRID CALIB

Transformer T3 winding 1-3, rectifiers SR27 and SR28, capacitors C25 and C26 form a voltage doubling network to provide -300 volts relative to the TWT cathode line. GRID CALIB. potentiometer R89 in series with R90 across the supply furnish a variable grid voltage of 0 to approximately -70 volts which is connected to the grid through EXT PULSE MOD switch SW4A and R91 when SW4A is in OFF position.

When the EXT PULSE MOD switch SW4 is in the ON position, the -300 volts is connected to the TWT grid through R91 to bias the TW tube to cutoff. An external positive pulse may now be applied to the TWT grid through EXT PULSE MOD connector S1, SW4B and capacitor C28 to grid modulate the tube. The amplitude of the pulse must exceed approximately 270 volts to turn the tube on.

The TW tube in this amplifier is of the convergent flow type and GRID voltage affects focus. The transition from -300 volts to operating grid value must be made very rapidly, otherwise high helix current and hence trip out would occur. Diode V10 serves as a clamp during pulse operation to limit the grid voltage from exceeding the normal CW value as set by the GRID CALIB potentiometer R89. In the OFF position of SW4B the junction of C28 and R92 is connected to +280 volts to decrease the voltage change across C28 when EXT PULSE MOD switch is changed from ON to OFF position.

SECTION 3 - INSTALLATION AND OPERATION

3-1 INSTALLATION

Upon receipt carefully unpack and inspect the instrument for damage received from transit. Should any damage be found, follow procedure outlined on "Shipment Damage Claim" page at the end of this manual.

This instrument is designed for either bench or rack operation in normal ambient temperatures. Air flow through the unit and from the solenoid exhaust should be completely unrestricted. Operation in the presence of very strong magnetic fields should be avoided unless external magnetic shielding is provided. Primary power requirements are 105 to 125 volts, 50 to 60 cps, approximately 1200 VA. If operation at other voltage or frequency is contemplated, consult manufacturer.

The 526, 527, 528 instruments are supplied with grey sheet metal sides containing handles. If the instruments are to be rack mounted, the screws on each handle side except those holding handle, should be taken out and the sides removed. Unit is now ready for inserting into rack. Supports should be provided in the rack to carry the weight of the unit upon its insertion or removal.

3-2 INITIAL OPERATION

1. Before turning on power, set panel controls:

   ANODE to MIN
   HELIX to 3000
   METER switch to HELIX
   EXT PULSE MOD to OFF

2. Turn on power and allow instrument to warm up at least 5 minutes.

3. Depress HIGH VOLTAGE ON switch.

4. Slowly advance HELIX control to operating value specified on TW tube data sheet. Note that as HELIX is advanced, helix current should be well below 3 ma. If helix current is near or exceeds 3 ma the TWT probably requires realignment in its solenoid. See Paragraph 4-6 for alignment procedure.

5. Slowly advance ANODE control to MAX. Before MAX position is reached helix current will peak and then drop down to an operating value well below 3 ma. Should helix current remain near or exceed 3 ma, the TWT will require realignment as noted above.

6. When ANODE has been advanced to MAX and HELIX to value specified on tube data sheet with helix current at or below its maximum value, change METER switch to COLLECTOR X20. Current should be at or slightly greater than the operating value of cathode current given on the TW tube data sheet enclosed at the rear of this manual. If current reading is too low, ANODE CALIB. control near top right side of chassis requires resetting. Remove top dust cover for access to control. Adjust until rated cathode current given on tube data sheet is obtained, alternately checking helix current to assure it remains below maximum value. If unable to obtain rated value with helix current below 3 ma, the TWT requires realignment.

7. Apply RF. Input power up to 1 watt will not cause damage. However, only the normally required level of a few milliwatts or less should be used. If RF output can be observed, adjust, if necessary, HELIX voltage slightly for optimum output. See also sub-section following, titled SYNCHRONISM. If RF output cannot be measured, connect a 1/2% or better accuracy voltmeter to read HELIX VOLTAGE between HELIX and CATHODE tip jacks at rear of instrument and set HELIX control to give a measured voltage of exactly that specified on TW tube data sheet.

8. If significant line frequency is observed, very slight repositioning of the TW tube in the solenoid may be required to null out stray magnetic fields from the power transformers in the instrument. Both helix current and AC field nulls occur at essentially the same mechanical positions, so slight turning of the adjusting screws, usually will give best modulation minimum without appreciably affecting helix current. Be sure that adjusting screws are locked at the best position and adjusting hole covers on solenoid are in proper place.

9. Resetting of ANODE control and a recheck of helix voltage, as described in 4 and 5 of above, may be necessary after one hour to correct for slight warmup drift. Position of ANODE control on panel should be noted so that it can easily be reset, should it accidentally be changed.

10. METER switch should be left in COLLECTOR X20 position during normal operation. An occasional check of helix current is recommended.

3-3 SYNCHRONISM

When the velocity of the electron stream and the progressive velocity of the RF signal are essentially the same, they are said to be in SYNCHRONISM. When

operation at a single frequency is contemplated, helix voltage can be adjusted to synchronous value, to give maximum gain and output at that frequency. When operation over a wide band of frequencies is contemplated, the helix voltage adjustment should be made to the factory determined value. At this setting synchronism usually occurs at some frequency usually near the high end of the band. Even though other frequencies are off synchronism, rated broadband response results.

3-4 REPEAT OPERATION

1. Before turning on power, turn ANODE control to MIN.

2. Turn on power and allow 5 minutes warmup.

3. Depress HIGH VOLTAGE ON switch and raise ANODE to MAX., noting that helix current does not exceed 3 ma and should drop well below this at MAX position. If too high, turn ANODE to MIN and follow procedure outlined in INITIAL OPERATION Paragraph 3-2 above, to optimize performance.

3-5 OPERATION AS AN AMPLIFIER

Amplification is linear for RF output up to 6 db below saturation. Further drive beyond this level causes the output to flatten and then decrease. Operation in the region of saturated output is non-linear, causing appreciable distortion and harmonic content in the output signal.

3-6 OPERATION AS A BUFFER

The Models 526, 527, 528 can serve very effectively to isolate a microwave signal source from a load. Reflections from mismatches, load variations, and the effects of modulation will not appreciably affect the impedance of the input terminals of the amplifier. The attenuator on the TW tube helix provides approximately 55 db attenuation between input and output, so load changes will be isolated from the source by this 55 db attenuation less the gain of the amplifier. The extreme case of a short or open circuit would be to change the VSWR of the amplifier input by about 7%.

3-7 OPERATION AS AN OSCILLATOR

The use of an external feedback circuit involving a passive resonator such as a cavity, will permit use of the TW tube amplifier as an extremely stable fixed frequency or wide range oscillator. Oscillation results when total loop phase shift is in the vicinity of $n \times 360^{\circ}$ producing positive feedback. This is accomplished by careful adjustment of helix voltage. Since helix voltage accelerates the electrons in the beam, it determines their velocity through the helix. Transit time and phase between output and input of the TW tube therefore, varies with

helix voltage. When a continually adjustable resonator is employed, it is necessary to optimize phase with the HELIX control progressively across the band. Otherwise, a series of oscillation modes will occur as phase of the TW tube amplifier rotates. A directional coupler or non-dissipative attenuator should be employed in the feedback line to minimize amount of output power fed to the input. This reduces harmonics and makes available almost all output power to drive a load.

SECTION 4 - MAINTENANCE

4-1 GENERAL

CAUTION: Extremely dangerous high voltages exist in this instrument. Observe the utmost care when checking or making repairs.

Routine maintenance should consist of the following:

1. Check blower operation every three months or after 1000 hours use, and oil bearings with a few drops of light machine oil in the oil tubes provided. Regular attention to the blower is essential since its failure could result in damage to the TW tube from overheating.

2. Test at regular intervals the power supply tubes to detect marginal performance. Any voltage regulator tubes removed for test should be returned to their original sockets. INTERCHANGING OR REPLACING VOLTAGE REGULATOR TUBES WILL NECESSITATE RECALIBRATION OF HELIX SUPPLY VOLTAGE.

3. As TW tube ages, preset ANODE CALIB control may require readjustment to maintain rated collector current when panel ANODE control is at maximum.

4-2 CALIBRATION OF HELIX SUPPLY VOLTAGE

Calibration of helix supply voltage is accomplished by connecting an ungrounded voltmeter having 1/2% accuracy or better to the Helix Voltage test points on the rear of the unit. Unlock the HELIX CALIB control, located near the right top side of chassis. With TWT disconnected, move panel HELIX control over entire range and note readings. Adjust HELIX CALIB control so that voltage indications are within ± 2% for any setting. Lock HELIX CALIB control.

4-3 TROUBLE SHOOTING

Should a failure occur, follow a logical procedure to locate the cause. Refer, if necessary to the THEORY OF OPERATION section and the schematic diagram included in this manual. Blown fuses should be replaced with 250 volts, type 3AG.

Power supply tubes can be observed to determine if heaters are operating and voltage regulator tubes lit, by removing screws, holding top dust cover and sliding it rearward. Operating voltages for the traveling wave tube may be measured as described below. Correct voltages are indicated on the circuit diagram.

Helix: Helix and Anode voltages relative to cathode are available at tip jacks on rear cover. CAUTION: Use high resistance, ungrounded DC voltmeter, HIGH VOLTAGES EXIST ON TERMINALS.

The Grid and Heater voltages may most easily be checked by removing power from the instrument and disconnecting the TWT connectors from sockets S2 and S5. The electrode voltages are then accessible (power on) at the connector pins. Use a high resistance DC voltmeter insulated from ground in making measurements. Refer to schematic diagram and check out sheet for correct values and polarity.

If tubes have been tested and found to be normal and supply voltages are incorrect, it is recommended that power be disconnected and faulty components located by a systematic resistance check.

For access to chassis components remove right handle side and cover side.

For access to solenoid chassis remove left handle side and cover plate.

For access to solenoid supply transistor located in air stream of blower, proceed as follows:

1. Remove screen, bottom plate, L.H. handle side and cover side.
2. Remove two #6-32 screws which are on L.H. transistor bracket (as viewed from front of unit) accessible through clearance holes in solenoid chassis.
3. Remove two #6-32 screws on R.H. bracket accessible from inside unit near blower.
4. Blower may now be removed.
5. Pull bracket holding transistor out from blower until transistor is accessible.
6. Use care in mounting; use heat sinks when soldering connections to transistor.
7. Use reverse procedure for reassembly.

For access to panel components, remove top dust cover and/or bottom plate. For access to panel indicators and fuses, blower must be removed. (See above.)

Components mounted in solenoid sub-chassis are accessible by removing three screws holding sub-chassis to solenoid chassis.

CAUTION: Use heat sinks during soldering operations on transistors and diodes.

4-4 BLOWER REPLACEMENT

Remove bottom plate and top dust screen, remove four mounting screws (6-32) as described in Paragraph 4-3.

Disconnect two transistor mounting brackets from blower housing.

Remove blower leads from barrier strip on solenoid chassis.

Blower may now be removed. In reassembly follow reverse procedure.

4-5 TRAVELING WAVE TUBE REPLACEMENT

1. Remove top dust screen.
2. Remove RF cover plate from front panel.
3. Disconnect TWT lead connectors.
4. Loosen TWT adjusting hole cover for access to TWT locking screws.
5. Loosen TWT locking screws.
6. Tube is now free for removal through front panel.
7. Center new tube in solenoid and place TWT clamp to scribe line on shell. Observe due caution to prevent damaging the tube.
8. Replace cover plate and make RF connections. Do not connect TWT power plug - see alignment procedure.
9. Use care in making waveguide connections to avoid undue strain on the RF connectors. The tube is held in place in the instrument by the TWT adjusting screws. Excessive pressure on the connectors could result in misalignment or damage to the tube.

4-6 TRAVELING WAVE TUBE ALIGNMENT PROCEDURE

Realignment of the TWT within the solenoid is necessary after TW tube replacement

or where de-focus has occurred due to repair, shock or other reasons.

1. With the power off, disconnect TWT power plug.

2. Set panel controls as follows:

   ANODE to MAX
   EXT PULSE MOD to OFF
   METER switch to HELIX

3. Turn on power and allow amplifier to warmup for five minutes.

4. With at least a 20,000 Ω/V voltmeter, set helix, anode and grid voltages to values shown on tube data sheet. Use ANODE CALIB and GRID CALIB potentiometers (located on right hand chassis upper front). CAUTION: HIGH VOLTAGE, USE EXTREME CARE IN MAKING THESE MEASUREMENTS. Use HELIX control on panel in setting helix voltage.

5. Turn off power and connect TWT power plugs.

6. Set ANODE to MIN

7. Turn on power.

8. Alignment is accomplished by removing top perforated dust cover and adjusting the TW tube positioning screws at each end of the solenoid. Orient TW tube to obtain the lowest HELIX current, all the while advancing the ANODE control. ADJUST CAREFULLY TO AVOID HIGH HELIX CURRENT DURING ADJUSTMENT. Should helix current accidentally exceed 3 ma, overcurrent relay will shut off power supply. Operation can be restored by turning ANODE control counterclockwise and then again depressing HIGH VOLTAGE switch to ON. If helix overcurrent trip occurs again, turn EXT PULSE MOD switch to ON. This puts -300 volts on grid so that a rough alignment can be made without trip out. After obtaining control of helix current in this position, return EXT PULSE MOD to OFF for greater sensitivity before continuing with the alignment.

   Positioning of the TW tube is most easily accomplished with two screwdrivers in each end. Starting with the tube approximately in the center of the solenoid, slowly wobble the tube with the alignment screws to minimize helix current. Adjust alternately with the two top screws at each end. After a minimum setting is reached, one screw should be turned, usually causing helix current to increase, and then the null relocated by turning a different screw. Often the new null is lower than the original. Reverse direction of turning if the new null is higher. Slight rotation of the TW tube may also result in a lower minimum. With a little care, helix current usually can be reduced to a safe value. Locking screws on bottom should be tightened enough to prevent the tube

shifting during normal handling of the instrument. Be sure to replace adjust hole cover to prevent air loss and overheating.

Maximum helix current (under drive) up to about 3 ma is safe. However, the lower the current, the less chance that gas will be driven from the helix due to high temperature operation. Gas would soon damage the cathode emission and render the TW tube inoperative. Lower current also reduces modulation of the RF output by beam noise and stray magnetic fields.

4-7 REVERSAL OF RF INPUT AND OUTPUT

The RF input and output may be reversed in the field.

To change from RF front to RF rear order parts:

1.	903433A	Front Blank Cover Plate
2.	903457A	Rear RF Plug Mounting Plate or
	903458A	Rear Waveguide Cover Plate

To change from RF rear to RF front, order parts:

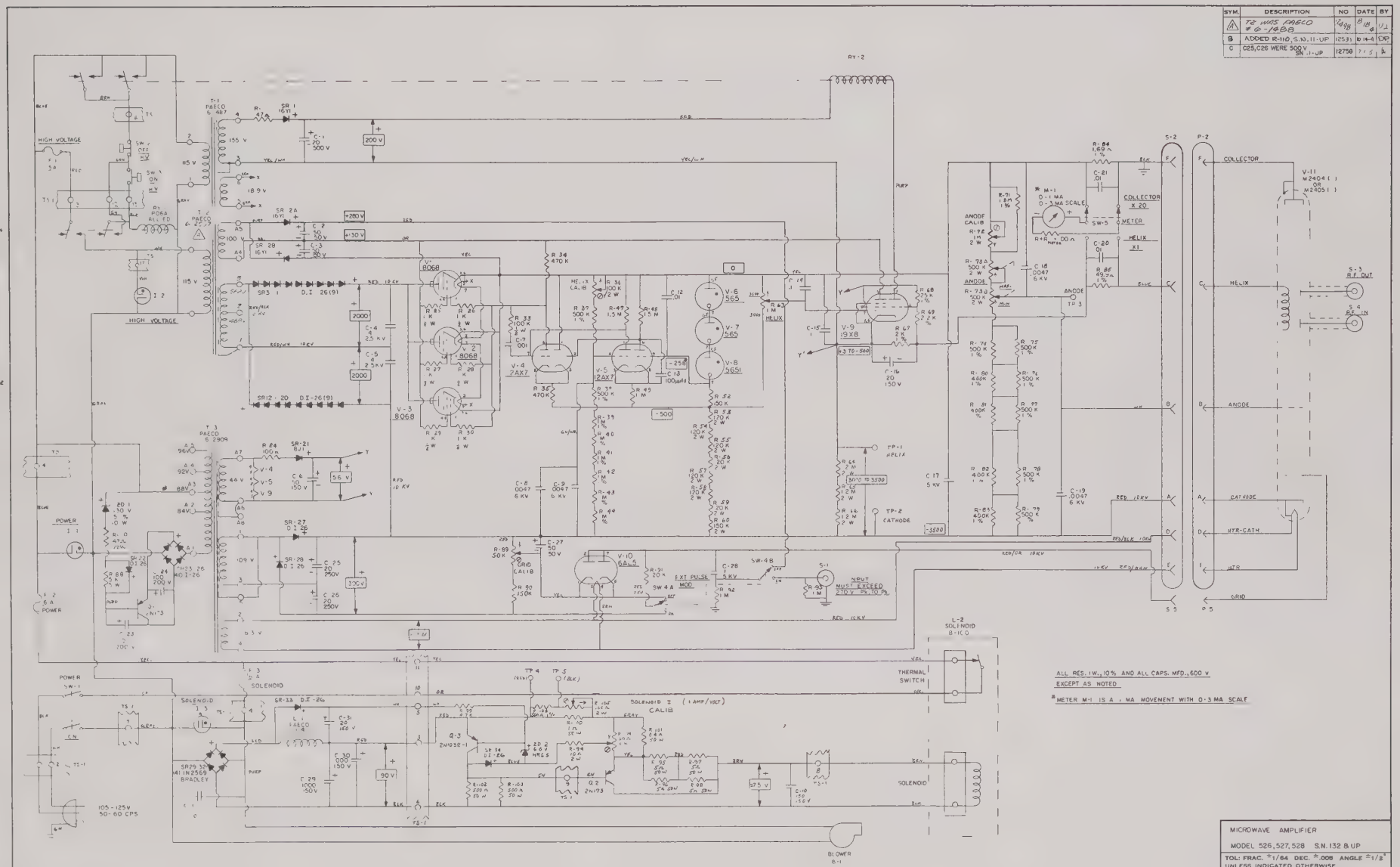
1.	904047A	Rear Exhaust Screen
2.	903434A	Front RF Plug Mounting Plate or
	903431A	Front Waveguide Cover Plate

To change proceed as follows:

1. Remove TW tube as described in Paragraph 4-5 above.
2. Remove blower as described in Paragraph 4-3 above.
3. Remove transformer and capacitor sub-assembly mounted with 6-32 screws.
4. Remove two air brackets and move to opposite position. (Front to rear of unit or vice versa.)
5. Remove solenoid spacer plate and move to opposite position.
6. Remount transformer and capacitor sub-assembly in opposite position.

4-8 TRAVELING WAVE TUBE WARRANTY

All workmanship and materials, except the traveling wave tube, are guaranteed for one year. Details concerning warranty adjustment are presented on "Shipment Damage Claim" page at the end of this manual. Details concerning the TWT warranty are presented on the "Tube Warranty and Replacement Procedure."


SYM. | DESCRIPTION | NO | DATE | BY
A | TO MOS PASCO #6-1858 | 11498 | 9/18 | WJ
B | ADDED R-110, S.N. 11-UP | 12531 | 10-14 | DP
C | C25,C26 WERE 500 V SN 1-UP | 12758 | 7/5 | k
ALL RES. 1W., 10% AND ALL CAPS. MFD., 600 V EXCEPT AS NOTED
*METER M-1 IS A 1 MA MOVEMENT WITH 0-3 MA SCALE
MICROWAVE AMPLIFIER
MODEL 526, 527, 528 S.N. 132 & UP
TOL: FRAC. ±1/64 DEC. ±.005 ANGLE ±1/2°
UNLESS INDICATED OTHERWISE
ALFRED ELECTRONICS
DRAWN S.K.S. | DATE 11/5/62 | APPR'D R.F.M. | DWG NO. 9006210

HUGGINS LABORATORIES
ENGINEERING NOTES

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GENERAL INFORMATION ON TRAVELING-WAVE TUBES

R. A. Huggins*

Engineers who design circuits which use conventional low frequency vacuum tubes usually have at least a speaking acquaintance with their theory of operation. In designing circuits, or in deciding which type of tube to use, careful use is made of the various characteristic curves associated with these tubes. The following discussion will similarly acquaint the applications engineer with the simple theory of the operation of the traveling-wave tube and familarize him with the various characteristic curves which describe its operation.

MICROWAVE AMPLIFICATION

As the microwave region of the radio frequency spectrum came into practical engineering use, devices were needed which could function as better amplifiers and oscillators. Above a few hundred megacycles conventional vacuum tubes no longer amplify properly because the period of one cycle of the radio frequency wave approaches the time it takes the electrons to travel from cathode to anode. As a result the amplification factor of the tube decreases with increasing frequency until no useful gain can be obtained. This is known as the transit time effect.

The first device which served as a practical amplifier above a few hundred megacycles actually made use of the transit time effect. This device, known as a klystron, became useful primarily as an oscillator. The klystron, however, is also capable of acting as an amplifier. Klystron amplifiers are capable of giving high values of amplification, but they have two serious limitations for many applications: They are relatively narrow band devices which usually have no more than a few megacycles bandwidth between half-power points, and tuning the amplifier to different frequencies requires a mechanical adjustment. The klystron is, however, the forerunner of a general class of microwave electron devices which utilize transit time effects in electron beams. This general class of devices includes the traveling-wave tube (TWT).

A klystron is a narrow band device because it involves the use of a very sharply resonant, high-impedance tuned circuit. It is necessary for a klystron to use such a circuit because interaction takes place with the electrons over very short physical distances, and it must develop high electric fields to have efficient interaction with the electrons. It was reasoned, however, that one might obtain a very broadband amplifying device by using a low-impedance, broadband circuit which developed relatively small electric fields that interacted with the electrons over a long physical distance. Such is the basis on which the traveling-wave tube works, and this basic concept led to a wide range of devices which are useful as broadband amplifiers and oscillators in the microwave region.

The traveling-wave tube yields high values

*President, Huggins Laboratories, Inc.

of amplification over wide frequency ranges with no mechanical tuning mechanism or variation of any voltages or currents applied to the tube. Power amplification greater than 10,000 (i.e., 40 db gain) over a 2:1 frequency range has been obtained with this type of tube. The actual number of megacycles covered by such tubes can be a staggering figure. For example, an operating bandwidth of 2000 megacycles has been obtained in one typical tube type; 7000 megacycles has been obtained in another.

Tubes can be designed to emphasize various special characteristics. For instance, tubes are built which have low noise properties, high power output, or controlled variations of gain with frequency. Many special tubes are designed and built for particular applications.

FORWARD-WAVE HELIX TYPE AMPLIFIER

Among the simplest circuit elements which satisfy the broadband low-impedance circuit requirement of the traveling-wave tube is a simple helical transmission line. On this so-called helix, the radio frequency energy essentially travels at the velocity of light along the wire from which the helix is wound. Since the wire and the energy follow this helical path, progress of the energy along the axis of the helix is at some fraction of the velocity of light. This velocity is determined by the geometry of the helix (i.e., circumference and pitch) and by the dielectric loading due to the structure which supports the helix. The fields associated with this "slow-wave" extend outward and inward into the region adjacent to the helix, and it is into this region that electrons are sent to interact with the waves.

If electrons are directed along the axis of the helix at essentially the same velocity as the waves, an interaction between the waves and electrons occurs wherein the electrons become bunched. As the electrons progress along the axis they become packed into tighter and tighter bunches. Simultaneously, the radio frequency fields on the helix increase in magnitude as they progress down its length. The increase in energy of this "growing wave" is just balanced by a decrease in the average kinetic energy of the electrons in the beam. In other words, the electrons, on the average, have been slowed down and have given up just enough energy to account for the increasing energy or power level in the waves on the helix.

In practice, the electron beam is formed by an electron gun and focused down the center of the helix to a collector electrode at the farther end (see Figure 1). The electron beam is maintained in a tight pencil beam throughout the length of the tube by the confining forces of a longitudinal magnetic field which surrounds the tube. Electron velocity is determined by the voltage difference between the cathode in the electron gun and the helix, and this voltage difference is ad-

Figure 1. Schematic View of a Traveling-Wave Tube.

justed to give the electrons the right velocity for interaction with the waves. The signal to be amplified is coupled onto the end of the helix nearest the electron gun and propagates along the helix in the same direction as the electron beam. Because of the interaction, the fields on the helix grow exponentially with distance, and these amplified waves are coupled off the helix at the end farthest from the electron gun.

The devices which couple the energy onto and off the helix are special directional couplers which are in themselves helices. These helices are outside the vacuum envelope and are matched to the input and output coaxial transmission lines. This type of coupler is capable of transferring most of the energy from the lines to the main helix, which is inside the vacuum envelope, without making physical contact with the helix. These "coupled helix matches" have the additional advantage of having very wideband transfer characteristic. Further, they are capable of presenting a standing-wave ratio to the coaxial transmission line of 1.5:1 or less.

SPECIFIC CHARACTERISTICS

In the following sections, various characteristic curves that are encountered in traveling-wave tube operation are discussed.

Helix Voltage vs Frequency. A helix is usually designed so that the "slow-waves" travel at a velocity in the range of 1/10 to 1/30 of the velocity of light. If the wave velocity is examined as a function of frequency, it is found that a helix has a general characteristic curve similar to that shown in Figure 2.

In region A, wave velocity varies as a function of frequency; in region B, wave velocity is essentially independent of frequency. A broadband amplifier is normally operated in region B – the "non-dispersive region."

As mentioned before, the electrons must travel at essentially the same velocity as the waves (synchronous velocity) in order to obtain the growing wave interaction. Since the velocity of the wave varies as a function of frequency, the velocity of the electrons must also be varied so that interaction is maintained. Inasmuch as the velocity of the electrons is determined by the voltage difference between the cathode and the helix, there is also a characteristic curve of synchronous helix voltage as a function of frequency (see Figure 2).

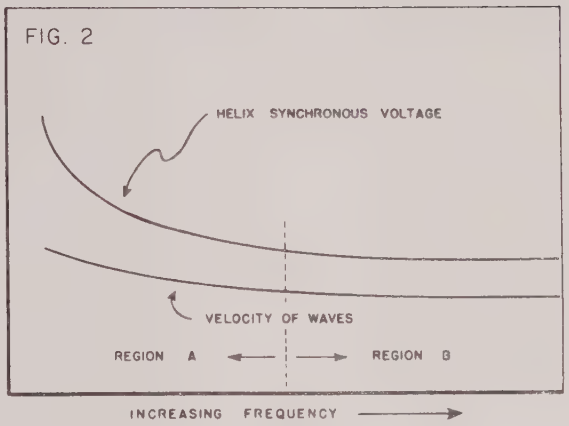

Figure 2. Phase Velocity of the Waves and Synchronous Helix Voltage as a Function of Frequency.

The reason a helix type traveling-wave tube can amplify over wide bandwidths without changing helix voltage can now be easily seen. In the non-dispersive region the synchronous voltage is essentially independent of frequency. That is, the helix voltage which gives the desired interaction between the waves and electrons can be fixed at one value, and this will be the correct value to provide interaction and amplification over a wide range of frequencies.

Gain vs Helix Voltage. To obtain the greatest interaction between the waves and the electrons, and thus the greatest amplification, the helix must be operated at synchronous voltage.

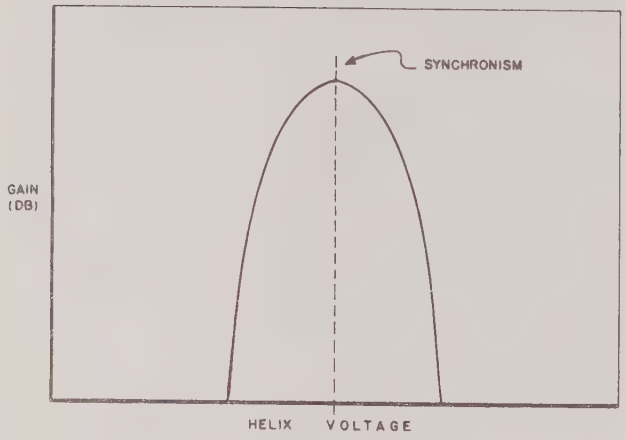

Figure 3. Gain as a Function of Helix Voltage.

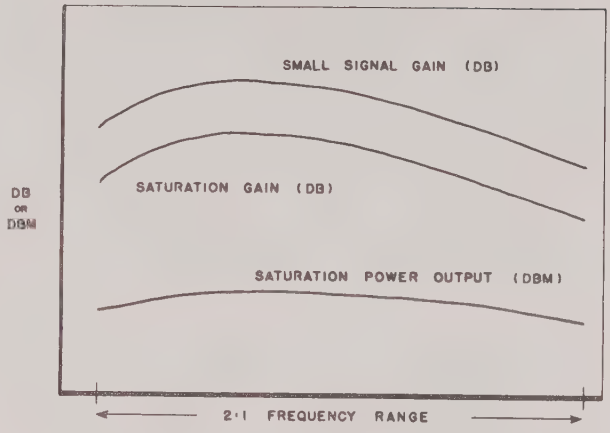

Figure 4. Gain and Power Output as a Function of Frequency.

Should the helix voltage be varied away from synchronism, the gain will decrease as shown by the curve in Figure 3. This characteristic of the TWT is parabolic in shape.

Gain and Power Output vs Frequency. Figure 4 shows a typical plot of gain vs frequency for a fixed value of helix voltage. Small-signal gain is obtained for all values of input signal level except those which drive the tube near its maximum or saturation power output. Saturation gain is the gain obtained when the tube is driven to its saturation power output level. It is seen that the gain and power output curves generally reach a maximum near the center of the band and droop off toward the band edges.

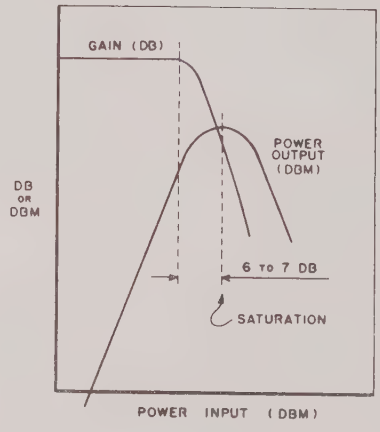

Figure 5. Gain and Power Output vs Power Input at a Fixed Frequency.

Power Output and Gain vs Power Input. Figure 5 shows the variation of power output and gain as a function of power input at a fixed frequency. The amplifier is linear until the power input is within 6 to 7 db of the value which drives the amplifier to saturation. At this point the power output curve begins to droop over, and gain of the tube begins to decrease. At saturation the power output is a maximum, and gain has decreased to the saturation gain level. As the tube is driven beyond saturation the power output drops off, and gain continues to decrease. To obtain maximum power output from an ordinary traveling-wave tube, the right amount of power input must be applied. As will be noted, the saturation region does not exhibit the leveling off or flat saturation characteristic that is found in conventional low frequency amplifier tubes.

Gain vs Beam Current and Grid Voltage. Figure 6 shows that the gain at any fixed frequency is essentially a function of the 1/3 power

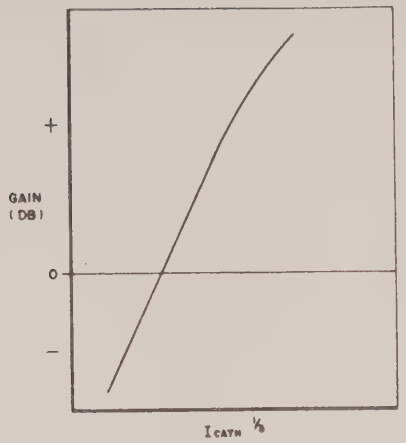

Figure 6. Gain vs Beam Current.

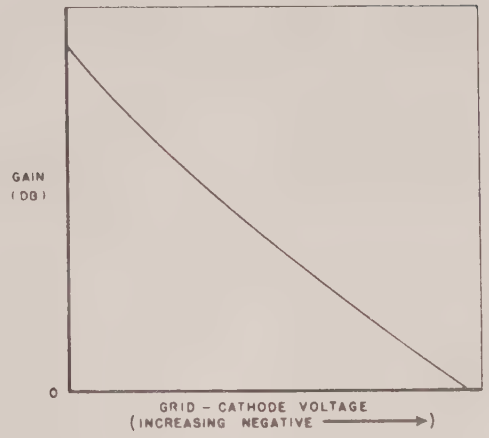

Figure 7. Gain vs Grid Voltage.

of the beam current, and as beam current decreases, gain decreases. Figure 7 shows that the gain of the tube decreases as the grid electrode is made negative with respect to the cathode. This results from the fact that operating the grid negative with respect to the cathode causes the beam current to decrease.

Should the beam current be decreased below a certain value as shown in Figure 6, the gain of the tube measured in db becomes negative, (i.e., the tube is acting as an attenuator). If the beam current is reduced to zero, the net "cold" attenuation of the tube is available. The total change in signal output level as beam current is decreased from its normal value to zero is equal to the sum of the net gain of the tube plus the cold attenuation. This can approach a variation in signal level of about 100 db. Such a change in signal output level is accomplished merely by varying the control grid voltage.

SPECIAL CHARACTERISTICS

Low Noise Amplifiers. A typical low power amplifier may exhibit a noise figure of 20 db. Certain applications require lower noise figures than this. Techniques are available in electron gun design whereby the "shot noise" in the beam can be "de-amplified" before it reaches the beginning of the helix. Special purpose tubes built in this fashion have reached noise figures as low as 6 db.

Narrow Band Amplifiers. Where an application does not require extremely wide bandwidths, tubes can be designed to operate in the dispersive region of the tube characteristic where the velocity of the waves varies as a function of frequency (see Figure 2). In this region, operation at a fixed voltage leads to amplification over only a relatively narrow band of frequencies. Extremely high values of gain (e.g., 60 to 70 db) can be obtained because the problem of controlling spurious oscillations is much simplified since the tube exhibits gain over only a relatively narrow band.

Special Gain Variation. Sometimes special requirements are imposed on the gain variation of the tube as a function of frequency. Tubes can be designed which exhibit an essentially constant value of gain across the band. Others have been built which have linearly increasing gain with frequency. Various other combinations are also possible.

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MICROWAVE MEASUREMENT TECHNIQUES

L. A. Roberts *

As traveling-wave tubes come into more common use, the need becomes apparent for clarification of the various measurement techniques involved in evaluating tube characteristics. In such measurements emphasis must be placed upon broad-band, untuned measuring techniques and test equipment since the traveling-wave tube is a very broadband device. Otherwise, much time would be lost in the repetitive and laborious adjustment and tuning of narrow band devices to make point-by-point measurements across wide frequency ranges.

In this Engineering Note we will concern ourselves with the measurement of small-signal gain, power output, standing-wave ratio, insertion loss, and noise figure. Though automatic and more modern techniques may be available, the methods discussed herein will prove both useful and reliable. Further, these methods require commonly available and relatively inexpensive test equipment.

The types of broadband test equipment commonly used are:

1. Self-tracking tunable signal generator with calibrated power output.
2. Untuned coaxial crystal detector.
3. Untuned coaxial bolometer or thermistor mount with self-balancing power bridge.
4. Broadband coaxial fixed attentuator.
5. Coaxial switch (SPDT).
6. Coaxial slotted section (for VSWR measurements) with untuned detector.
7. Coaxial or waveguide directional coupler.
8. Flourescent noise source.

The emphasis on measuring equipment is placed upon coaxial systems. This is because coaxial test equipment has inherently wideband properties. Waveguide equipment is utilized only when equivalent coaxial equipment is not available or will not do an equivalent job.

SMALL-SIGNAL GAIN MEASUREMENT

A rapid and satisfactory method of measuring gain is to make an insertion gain measurement using the substitution method. This method requires no knowledge of the detector characteristics, nor is absolute power calibration of the signal generator necessary. Accuracy of the measurement depends only on the calibration accuracy of the signal generator output attenuator.

Figure 1 shows a block diagram of the small-signal gain measurement system. With the coaxial switches in position 1, the output of the sig-

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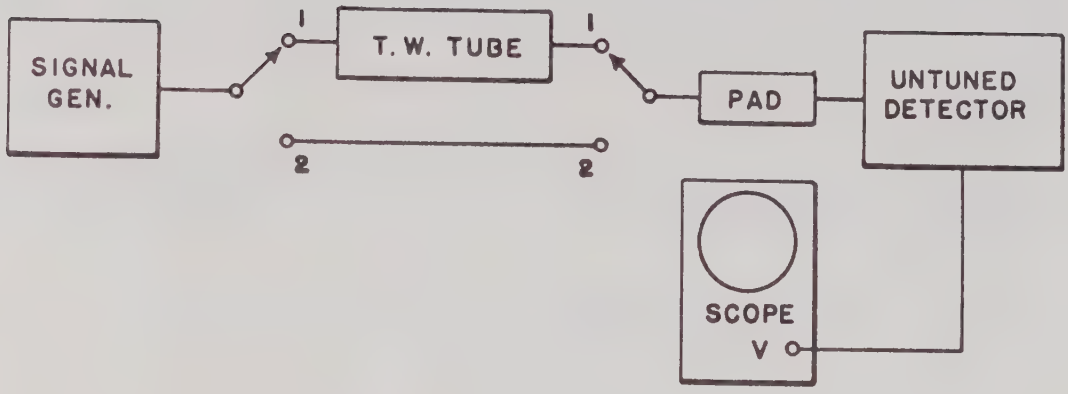


Figure 1. Block Diagram of Gain Measurement System.

nal generator (which has a matched 50 ohm output) is fed to the TWT input through a coaxial single-pole double-throw switch. The output of the TWT is in turn fed through another coaxial switch and a 6 db minimum coaxial fixed attenuator to the untuned detector (If the detector is matched to the coaxial switch, the pad can be eliminated). The detector output is then applied to the vertical deflection channel of an oscilloscope. When the switches are placed in position 2, the tube is by-passed.

Procedure. Apply pulse or square wave modulation to the signal generator. With the tube operating and the switches in position 1, the output attenuator of the signal generator is adjusted to give some convenient deflection on the scope. This is attenuator reading 1. The switches are then placed in position 2 and the attenuator readjusted to give the same deflection on the scope. This is attenuator reading 2. The insertion gain of the tube is then the difference between attenuator readings 1 and 2 measured in db.

Precautions. Both the signal generator and the detector must present good impedance matches as seen by the switch. If they are not matched, reflection losses can give up to several db error in gain. This is the reason for the pad ahead of the unmatched detector, for a 6 db pad guarantees a VSWR of at most 1.5:1.

Also, the switches used must have a low VSWR and very low crosstalk. Crosstalk is stray feedthrough from the input to output terminals of the DPST switch combination through the unused channel. The crosstalk ratio is measured with the TWT removed and is equal to the difference between the signal generator attenuator readings when it is adjusted for equal scope deflection with the switches in position 1 and 2. Regenerative feedback around the switches, which introduces errors in the gain measurement, will be prevented if the crosstalk ratio is at least 20 db greater than the gain of the tube being measured. If the crosstalk ratio exceeds 45 db, it probably cannot be measured with the system in Figure 1. The crosstalk ratio can be measured in such cases with the insertion loss measurement system soon to be described.

Further, care must be taken to insure that the output power level of the tube is at least 10 db below the saturation power level. This eliminates errors due to the decreasing gain characteristic of the traveling-wave tube in the region near saturation.

POWER OUTPUT MEASUREMENT

When making power measurements over wide frequency ranges, it is convenient to use broad-

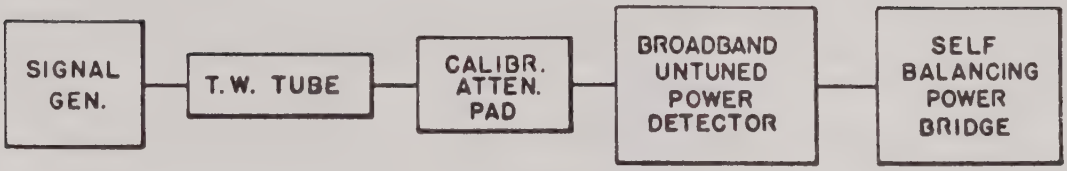


Figure 2. Block Diagram of Power Measuring System.

band (untuned) bolometer or thermistor mounts as power detectors. When these mounts are operated in conjunction with a self-balancing wattmeter bridge, they provide a convenient system for the measurement of absolute power.

If the power level to be measured is greater than the maximum allowable power input to the mount, a calibrated attenuator pad should be inserted ahead of the mount. The most convenient type of pad to use is the resistive film type which has attenuation characteristics that are essentially independent of frequency. Care must be taken not to exceed the maximum input rating of the attenuator.

If power levels to be measured are greater than the rated dissipation of standard attenuator pads, a directional coupler must be placed on the output of the tube. The main arm of the coupler is terminated with a broadband load, and the power detector, with appropriate pads, is placed in the auxiliary arm of the coupler. Broadband coaxial directional couplers with coupling ratios of 10 and 20 db from main arm to auxiliary arm are available.

Should gain measurements be made in conjunction with the power measurements, the power output of the signal generator must be calibrated using its power monitor at each frequency. For accuracy, the power output reading of the signal generator should be initially checked using the bolometer mount and the wattmeter bridge at least over the range of power levels that the bridge can accurately read. Small-signal gain measurements obtained with this equipment should check with the small-signal gain measurements made by the substitution method if the calibration of the attenuator pad and the signal generator is checked.

If all power measurements are recorded in terms of dbm (i.e., db with respect to one milliwatt), the readings of the power bridge, the attenuator (in db) and the signal generator need be merely added and subtracted to obtain power output and gain. Conveniently, most signal generators and power bridges are calibrated in dbm as well as milliwatts.

Figure 2 shows the block diagram of the power measurement system. The power output is given by the equation:

$$P_{out}\ (dbm) = \text{Pad Attenuation (db)} + \text{Ratio of Directional Coupler (db)} + \text{Power Bridge Reading (dbm)}$$

The gain of the tube is given by the equation:

$$\text{Gain (db)} = P_{out}\ (dbm) - P_{in} \text{ from Signal Generator (dbm)}$$

The above gain measurement is valid for both small-signal gain and gain measured in the saturation region and beyond.

STANDING-WAVE RATIO OR REFLECTION COEFFICIENT MEASUREMENT

For direct measurement of voltage standing-wave ratio (VSWR), the coaxial slotted line is the

simplest method. It is essential to have an untuned detector on the slotted line, however, in order to speed up broadband measurements.

When it is necessary to examine the VSWR continuously over a wide frequency range, and where fast checks are required such as on production test setups, the slotted line type of measurement becomes prohibitively time consuming and laborious.

For such situations, the measurement of reflection coefficient through the use of directional couplers is recommended. Two directional couplers which are connected so that one gives an output proportional to the incident wave and the other an output proportional to the reflected wave from the load are used. These two outputs can be detected and compared with a ratiometer to give a direct reading of reflection coefficient. The reflection coefficient is then converted to equivalent VSWR if necessary. The greater the accuracy required in the measurement of reflection coefficient, the higher must be the directivity of the directional couplers. In waveguide, directivity greater than 40 db over the waveguide range can be obtained which allows measurement of reflection coefficient of 0.1 with an accuracy of ±.02. This means that a load VSWR of 1.2 will give an indicated reading between 1.15 and 1.25. A waveguide to coaxial transition can be used to adapt the reflectometer to coaxial systems, but residual reflection in the transition limits the accuracy at low VSWRs.

Once the initial calibration is performed in such a reflectometer system, it is only necessary to tune the signal generator across the frequency range and read the reflection coefficient values directly. An excellent detailed discussion of this method, its errors and limitations, is given in the Hewlett-Packard Journal, Volume 6, Number 1-2, Sept. - Oct., 1954.

Even faster measurements can be made when a swept oscillator is employed. Reflection coefficient can be displayed directly on a scope as a function of frequency, and the measurement can be made at a glance.

INSERTION LOSS MEASUREMENT

Measurement of insertion loss in the range of 40 to 100 db (e.g., cold loss measurement in a traveling-wave tube) over a wide range of frequencies is not uncommon. Such a measurement cannot be made with a 1 milliwatt signal generator and a broadband detector, for this type of system does not have the power levels, nor the sensitivity, to measure much more than 45 db insertion loss.

Wideband measurements can be made quickly and easily, however, with the use of one or two traveling-wave tubes as amplifiers. Use of a traveling-wave tube with a noise figure of 20 db ahead of the detector gives a sensitivity into a broadband detector on the order of −65 to −75 dbm. This alone allows insertion loss measurements of 65 to 75 db. Further, if the output of the signal generator is amplified to the power level of one watt (+ 30 dbm) by using a medium power traveling-wave tube, the total insertion loss then measurable becomes 95 to 105 db.

Since traveling-wave tubes are broadband, untuned devices, the only adjustment necessary in this system as frequency is changed across the band is the tuning of the signal generator. The insertion loss measurement is made in the same manner as the insertion gain measurement shown in Figure 1 except for the addition of the amplifiers before and after the switches. Commercially available switches, when connected as shown in Figure 1, have been measured which have a combined crosstalk ratio in excess of 120 db This, of course, eliminates any crosstalk error in insertion loss measurements in the range of 95 to 105 db.

NOISE FIGURE MEASUREMENT

When one is interested in measuring noise

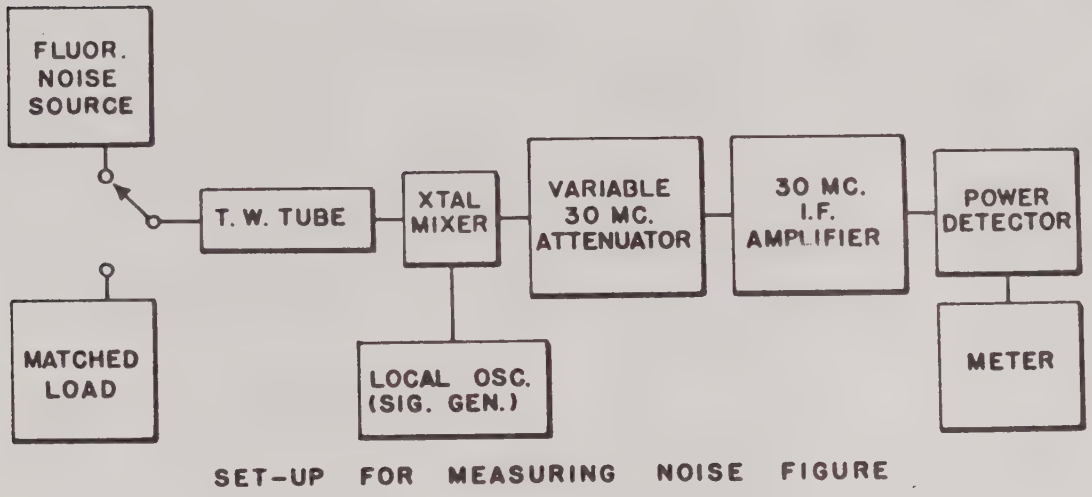


Figure 3. System for Measuring Noise Figure.

figure at a number of frequencies over a wide frequency band, a system which employs a fluorescent tube noise source and a superheterodyne receiver with a square-law second detector (i.e., a power detector) can be used. If noise figure does not vary too rapidly with frequency, a simple receiver can be used which employs an untuned crystal mixer, a local oscillator, a 30 mc IF strip, and a power detector. Note that no preselection or mixer tuning is used.

Without a preselector, the receiver will respond equally well to both the signal and image frequencies. With a 30 mc IF amplifier, these two frequencies will be only 60 mc apart. The measured noise figure will be an average of the true values at two frequencies 60 mc apart providing noise figure is not a rapid function of frequency. This is accurate enough for most purposes. If noise figure varies so rapidly that it will be appreciably different at two frequencies spaced 60 mc apart, then preselection is necessary.

The noise figure of an amplifier is defined as the ratio of the signal-to-noise ratio at the input of the amplifier to the signal-to-noise ratio at the output of the amplifier, That is,

$$F = \frac{(S/N)in}{(S/N)out} \qquad \text{(power ratio)}$$

When the measurement is made according to the method to be outlined, and a noise source whose level is 15.8 db above thermal noise is used, the above equation becomes:

$$F = \frac{37k}{\frac{P_1}{P_2} - 1} \qquad \text{(power ratio)} \qquad (1)$$

where, P_1 and P_2 are as defined in the measurement procedure below, and k, a number smaller than 1.0, is the cable loss in db between the noise source and the tube converted to a power ratio. (e.g., for cable loss = 1db, k = .794)

When a fluorescent noise source is used, it is not necessary to know the effective RF noise bandwidth of the receiver.

Procedure: The tube to be measured is connected into the system shown in Figure 3. The

power detector in the receiver may take the form of a bolometer or a thermistor operating into a self-balancing wattmeter bridge, or it may be a thermocouple whose output is connected to a microammeter.

With the TWT operating and the local oscillator tuned to the desired frequency, switch the tube input to the noise source. Adjust the variable 30 mc attenuator until the output meter indicates approximately full scale. This is reading P_1.

Then switch the tube input to the matched load. The output meter now indicates P_2. Insert the values of P_1 and P_2 in equation 1 and compute the noise figure. To determine the noise figure in db, merely convert this number to db.

Precautions: The accuracy of this measurement is based on the assumption that the receiver is linear. This will be true if the local oscillator signal is large enough to produce linear mixing and if the IF amplifier is operated in the linear portion of its characteristics

The measurements should be taken quickly enough so that power meter drift will not affect readings.

ALFRED

Tube Warranty and Replacement Procedure

Tube Replacement

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS or the tube manufacturer for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

On ALFRED supplied TWT and BWO tubes used in catalog instruments, ALFRED ELECTRONICS extends the full warranty given by the tube manufacturer and, in addition, offers the following:

Warranty for Huggins & ITT TWT's

Tubes are warranted unconditionally against defects in workmanship, materials, and construction for the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty for MEC TWT's and All BWO Tubes

Tubes are warranted unconditionally against defects in workmanship, materials, and construction for the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C).

TWT

Mfg.	Power	A months	B hours	C hours
Huggins	1 - 10 mw	6	500	2000
MEC	1 - 20 mw	6	1000	2000
Huggins	1 watt	6	250	1000
MEC	1 - 10 watt	6	500	1000
Huggins	low N.F. to 15 db	6	500	2000
MEC	low N.F. to 15 db	6	1000	2000
ITT	10 watt	2	50	500
	BWO			
All	0.5 to 40 GHz	6	200	2500

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

Return Authorization

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

Return Procedure

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

In-Warranty Failure - BWO Tubes

BWO tubes which fail in warranty will be replaced with a new tube. In case a BWO tube fails, please issue a purchase order for a new BWO tube at the tube list price and return the defective BWO tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and promptly returned.

Repairable or In-Warranty Failure - TW Tubes

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

Warranty Credit

Any applicable credit allowed under the terms of this warranty applies only toward the future purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF Cables

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

Special Conditions

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

3/1/66

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____
2. If not, what was done to adjust it? _____

   _____

   _____
3. Has proper cooling been maintained during tube operation? _____

   _____
4. Did helix overcurrent tripout occur? _____

   _____
5. Was environment normal? (specify) _____

   _____
6. Symptoms - (describe failure) _____

   _____

   _____
7. Operating conditions at time of failure (indicate any unusual conditions) _____

   _____

   _____
8. Name of person to contact regarding evaluation of failure _____

   Telephone No. _____ Signature _____

   Title _____

   Date _____

ALFRED

Tube Warranty and Replacement Procedure

Tube Replacement

All TWT and BWO tubes furnished in ALFRED instruments are available from ALFRED ELECTRONICS or the tube manufacturer for either warranty or out-of-warranty replacements. Current prices are given on the Replacement Tube Price List.

TUBE WARRANTY

On ALFRED supplied TWT and BWO tubes used in catalog instruments, ALFRED ELECTRONICS extends the full warranty given by the tube manufacturer and, in addition, offers the following:

Warranty for Huggins & ITT TWT's

Tubes are warranted unconditionally against defects in workmanship, materials, and construction for the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C) or one-year time period, whichever results in lesser credit.

Warranty for MEC TWT's and All BWO Tubes

Tubes are warranted unconditionally against defects in workmanship, materials, and construction for the period shown in Column A and the number of heater hours shown in Column B. To supplement the unconditional warranty, the tubes are warranted on a pro-rata basis for the rated number of heater hours shown in Column C or for one year, both computed from the date of original shipment by ALFRED, whichever expires first. The pro-rated adjustment will be based on the current list price of the tube and the unused percentage of heater hours (Column C).

TWT

Mfg.	Power	A months	B hours	C hours
Huggins	1 - 10 mw	6	500	2000
MEC	1 - 20 mw	6	1000	2000
Huggins	1 watt	6	250	1000
MEC	1 - 10 watt	6	500	1000
Huggins	low N.F. to 15 db	6	500	2000
MEC	low N.F. to 15 db	6	1000	2000
ITT	10 watt	2	50	500
		BWO		
All	0.5 to 40 GHz	6	200	2500

WARRANTY CONDITIONS APPLY ONLY TO TUBES LISTED ABOVE WHICH ARE USED IN ALFRED CATALOG INSTRUMENTS.

Return Authorization

TO OBTAIN WARRANTY CREDIT THE TUBE SERVICE REPORT MUST BE COMPLETED AND RETURNED WITH THE TUBE.

Return Procedure

In case a tube or instrument fails, please contact the factory or your local sales representative for advice or authorization to return either the tube or the instrument to the factory. NO TUBE OR INSTRUMENT WILL BE ACCEPTED FOR REPAIR OR CREDIT ADJUSTMENT WITHOUT WRITTEN AUTHORIZATION AND ACCOMPANYING SERVICE REPORT.

When the authorization is received, pack the tube in a rigid container (use original carton if available) at least 4" larger than the tube in each dimension. Wrap the tube with 1/4" of soft padding material and heavy kraft paper before placing in container. Pack at least 2" of resilient dunnage such as rubberized hair, foam, or similar shock absorbing material completely around the tube. Mark the container "FRAGILE" and ship PREPAID via air freight, air express or rail express. Do not ship via parcel post or air parcel post since experience has shown that fragile items are more apt to be damaged when shipped via these methods.

Use similar wrapping, packing and shipping provisions for an instrument. At least 6" of rubberized hair (or equivalent shock absorbing material) is required for an instrument.

In-Warranty Failure - BWO Tubes

BWO tubes which fail in warranty will be replaced with a new tube. In case a BWO tube fails, please issue a purchase order for a new BWO tube at the tube list price and return the defective BWO tube. Warranty credit will be issued and deducted from the price, subject to tube manufacturer's verification that failure was caused by tube malfunction. To qualify for maximum credit, it is essential that the defective tube be properly packed and promptly returned.

Repairable or In-Warranty Failure - TW Tubes

If the returned tube is found to be repairable, the user will be asked to issue a purchase order for repair charges determined by the original tube manufacturer. In general, the repair will be at no cost if the tube is in warranty and there is no evidence of misuse or abnormal conditions of operation.

Warranty Credit

Any applicable credit allowed under the terms of this warranty applies only toward the future purchase of a replacement tube from ALFRED ELECTRONICS. Cash settlements will not be made. In terms of this warranty, a replacement tube must be the same type as that on which credit is allowed. Credit for one tube only may be applied toward the purchase of a single replacement tube. Warranty credit remains in effect for a maximum of six (6) months from date ALFRED ELECTRONICS notifies the customer. All credits will be based on the purchase price of the tube which prevails at the time the order for a replacement tube is received by ALFRED ELECTRONICS.

BWO RF Cables

RF OUTPUT CABLE MUST ACCOMPANY BWO TUBES returned for warranty credit, repair or replacement. If rf output cable is NOT returned, the cable price is added to the normal BWO repair or replacement charge. For prices see Replacement Tube Price List.

Special Conditions

If a returned tube or instrument proves not to be defective after test and evaluation at ALFRED ELECTRONICS, the tube or instrument will be returned at the customer's expense.

The final determination as to whether the tube failed in normal operation thereby bringing it under the applicable warranty or whether the tube was misused thereby excluding it from application of the warranty provisions, lies solely with the tube manufacturer.

Data, warranty credit, and prices subject to change without notice.

3/1/66

ALFRED ELECTRONICS

Service Report

Instrument Model _____ Serial No. _____ Date Received _____

TW/BWO Tube Type _____ Serial No. _____ Date Received _____

Date First Tested _____ Date Placed in Service _____ Date of Failure _____

Total Number of Hours of TWT/BWO Heater Operation _____

_____

1. Was operation normal just prior to failure? Yes _____ No _____

2. If not, what was done to adjust it? _____

_____

_____

3. Has proper cooling been maintained during tube operation? _____

_____

4. Did helix overcurrent tripout occur? _____

_____

5. Was environment normal? (specify) _____

_____

6. Symptoms - (describe failure) _____

_____

_____

7. Operating conditions at time of failure (indicate any unusual conditions) _____

_____

_____

8. Name of person to contact regarding evaluation of failure _____

Telephone No. _____ Signature _____

Title _____

Date _____

SHIPMENT DAMAGE CLAIM

The instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim must be filed with the carrier. Have carrier agent inspect damage to instrument and packing crate and forward us a copy of his written report. You will then be advised of replacement or repair arrangements and disposition of the equipment. Please include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

ALFRED products are warranted against defects in workmanship and materials. This warranty is limited to repair or replacement of products or parts (except tubes, transistors, and batteries) which prove defective within one year after delivery to original purchaser. ALFRED ELECTRONICS is not liable for consequential damage.

If any fault develops:

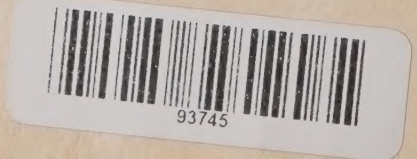
1. Notify us, giving full details of the difficulty, including the model number, type number and serial number. Upon receipt of this information, you will be sent service instructions or shipping data.

2. Upon receipt of shipping instructions, forward the instrument prepaid and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins when instrument is not covered by this warranty.

PACKING

The instrument should be packed in the original carton. If unusable or not available, use a wooden box with approximately three inches of excelsior or other shock-absorbing material surrounding the instrument. If desired, packing services of a local transfer and storage company may be employed.

CHAMPION CLASP NO. 55 6x9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